BASIC WAY SERIES

THE BASIC WAY TO ARITHMETIC

Orient Longmans

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THE BASIC WAY SERIES

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STATE INSTITUTE OF EDUCATION
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THE BASIC WAY TO ARITHMETIC

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EDITOR'S NOTE

The *Basic Way Series* of books dealing in a brief and simple manner with the theory and practice of Basic Education are written for those who teach or will teach in Basic schools. Basic Education has come to stay ; it has been adopted as our national system of education. Therefore, it is very necessary that there should be a wider, clearer knowledge and understanding of the main principles and merits of the system of Basic Education. The system breaks sharply with traditional practices which assume that the teacher's principal job is to impart knowledge and develop the skills which are determined largely by text-books. Should we just continue as we are doing or should we change with the changing needs of the child we seek to educate and of the times for which we educate him ? This series is a plea that our methods should so change and attempts to indicate the way it should be done.

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INTRODUCTION

More than fifteen years ago the scheme of Basic Education was commended to the country by Mahatma Gandhi to serve as the basis of national education. Although the scheme was put into practice without much loss of time in some of the provinces, it had to wait for its adoption as a national policy till India achieved her independence in 1947. But so far as the actual implementation of the scheme is concerned, even today the situation is far from satisfactory.

Why is it that in spite of the commitment and support of the government, Basic Education has not been able to make much headway? No doubt, the paucity of material resources and the unavailability of necessary personnel are mainly responsible for checking the growth of Basic Education at a quicker pace. But a lack of certain other prerequisites is also hampering its progress. One of the important requirements for the success of the scheme is to provide suitable literature for the use of teachers and pupils of Basic schools. Even an enthusiastic teacher gradually loses his zeal, when he finds no material worth the name which can guide and help him in meeting the peculiar demands of Basic Education.

The need for preparing books for the Basic school cannot be over-emphasized. In order to fulfil this need, all the public and private agencies interested in the speedier expansion of Basic Education must contribute their share. As such, the venture of Orient Longmans is commendable in planning to bring out THE BASIC WAY SERIES of which the first one, namely "What Basic Education Means" has already been published. The present book "The Basic Way to Arithmetic" is the second to come out in the proposed series.

The book is divided into two parts. The first part deals with the general principles of teaching mathematics in Basic schools. Here some of the important aspects of the subject have been brought out with special reference to the needs and opportunities of the Basic school. The second part is concerned with the techniques and procedures of teaching some specific units which are most important in mathematics from the viewpoint of their utility to a training for citizenship.

It has been the author's sincere endeavour to make the book as much useful to the Basic school teacher as possible within the limited space at his disposal. He would feel amply rewarded for his labour, if the book gives the teacher even a little guidance in helping children live more effectively.

JAMIA NAGAR, DELHI.
October, 1954.

DR. SALAMAT ULLAH

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PART I

GENERAL PRINCIPLES

1. Mathematics in the Basic Curriculum

Integrated learning versus subjectwise teaching

BASIC Education insists that learning should be based on integrated experiences acquired through meaningful activities. This view is opposed to the common practice where learning is confined to memorizing bits of knowledge of compartmentalized subject matter. This naturally raises the issue, "Why should, then, the Basic curriculum consist of separate subjects e.g. mother tongue, general science, mathematics etc. ?"

Is there a contradiction involved in this situation? Apparently there is. But a little thought would show that there is none. Basic Education is a system of compulsory education for all children in the age group of 6-14 years. This must be provided free of charge by the State at its own expense. Therefore, during this period every boy and girl of our country must be equipped with all that is basic to a training for citizenship. This is why the Basic curriculum seeks to provide a firm background of understandings, skills, abilities, attitudes, appreciations, etc., which is regarded necessary and fundamental for effective living in a democratic society. So the curriculum must contain a functional knowledge of all those subjects which can help achieve the above-mentioned aim. Of course, this knowledge should not be imparted to children subjectwise in isolation from their other activities and experiences. On the contrary, it must be well coordinated and correlated with their life so as to make it an integral part of their personality. There-

fore, the matter detailed under different subject heads in the Basic curriculum should not be looked upon as isolated bits of information to be treated separately. Rather, it should be considered as a whole meant for the guidance of the teacher, who would help children select materials that satisfy the needs of real situations as they arise.

The place of mathematics in the curriculum

What is the place of mathematics in the Basic curriculum? How does a skill in computation or a competence in solving mathematical problems make for an effective living ? Questions like these do not need theorising. It is quite obvious that in our advanced civilization, every citizen comes across various problems involving concepts of number and space in his daily life. He cannot do without them. He must acquire a reasonable efficiency in solving the number and space problems that occur in different life situations. Therefore, ability in mathematics is regarded as an essential part of the training for citizenship. Hence the importance of mathematics in the Basic curriculum.

Arithmetic should find its place in each of the Basic grades including the first. The programme of teaching arithmetic should develop with the growing needs of children in life, both in and outside the school.

Functional versus systematic arithmetic

In the traditional school arithmetic is taught in a logical order. For example, addition facts are introduced only after the children have systematically mastered counting and writing of numbers up to 100, or similarly multiplication is not started until the children have systematically memorized multiplication tables up to 10×10. On the other hand, in the so-called 'progressive' schools, there is a tendency

to minimize systematic practice in arithmetic under the plea that arithmetic can be effectively learnt by children only when they are confronted with a real situation in which they feel the need to acquire a certain knowledge in order to meet that situation. Thus the functional use of arithmetic is made to determine its teaching procedure. For example, when children run a stationery shop, it is claimed that they learn the essential facts of addition, subtraction, etc. functionally. But experience has shown that neither of the above procedures is adequate by itself.

We should neither exclusively insist on functional arithmetic nor on systematic arithmetic. Activities should be selected because of their general value to the children, not solely because of the opportunities they offer for arithmetic. The use of arithmetic in solving problems which arise soon proves the need for systematic practice. Activities make arithmetic meaningful, but children's functional experiences must be supplemented with systematic learning of arithmetic.

Aims of teaching Basic mathematics

This leads us to consider what aims and objectives should be realized through teaching mathematics in the Basic school. Here both the utilitarian and cultural aspects of mathematics must be emphasized so that the child may not only be able to apply his skill in solving his own mathematical problems, but he may also understand and appreciate the role of mathematics in the development of our culture.

In teaching mathematics the social and cultural values of the subject need proper emphasis. In the past the emphasis was wrongly laid on the disciplinary value of mathematics. The matter selected and the methods adopted were intended to impart a sort of mental training which was regarded as a unique and most important function of teaching mathe-

matics. It was claimed that this procedure would result in training the reasoning faculty of the mind. But this claim could not be justified on the basis of the actual achievements of the learner in the subject. The matter used for the 'mental gymnastics' often had no relevance to social needs, and, therefore, it could not succeed even in its proclaimed objective of sharpening the reasoning power.

Mathematics is so much needed in our social and cultural life that we cannot conceive of a world in which people were ignorant of the subject. How could people carry on their transactions like buying and selling, borrowing and lending, etc. without a knowledge of arithmetic ? How could people build their houses, weave cloth, make furniture, construct bridges and railways, and so on without the application of mathematics ?

Children in their homes and neighbourhood begin early to realize the social and cultural values of mathematics. They come across experiences that involve counting and measuring in their day-to-day life. The aim of the Basic school should be to strengthen and to widen these experiences in a systematic way, while children are working individually or collectively on any project involving mathematics.

To sum up, the child must be able to :—

1. Understand the value of number and space concepts in ordinary affairs of life.
2. Solve speedily and accurately the simple numerical and geometrical problems arising out of his craft work and other school activities and relating to his home and community life.
3. Think for himself, to concentrate, to make sustained effort and to understand and use precise statements whether expressed in words, symbols or diagrams.

II. Syllabus of Basic Mathematics

The course of study in mathematics may be based on a study of the mathematics itself, or on a study of the community's use for mathematics, or on a study of the child. The study of the mathematics itself leads us to break it up into convenient units of instruction and show their relations to each other. But a course of study based upon a consideration of the subject matter alone, is by no means adequate, as it does not provide any motivation for the learner. The study of the life of the community and the mathematics it uses points the way to a practical course in mathematics. The school must be able not only to identify the present needs of the community but also to visualize the emerging needs in the business and the industrial field around it. This is a very useful approach to mathematics, as it is based on a sound psychological principle that we learn most readily the things we feel the need of knowing. But in ascertaining the arrangement and the presentation of the subject matter the study of the child should be regarded crucial. The most fruitful question we can ask ourselves is this, "What mathematics is best suited to the needs of the child at a particular stage ?" This means what he needs for his present use and enjoyment.

Principle of flexibility

If we accept the above-mentioned bases as adequate for a course of study in mathematics, the proposed syllabus of Basic mathematics should not be taken as a rigid pattern to be adhered to in all the details according to the given order. The syllabus should rather be looked upon as a general outline of the material deemed more or less necessary for the training of citizenship. The teacher and children should feel free to choose their material in accordance with

the needs of the learning situations as they arise. It is quite obvious that while following this principle, no fixed pattern of subject matter can always be maintained. Both the order and the content of the subject matter are likely to be modified under this principle of flexibility.

Emphasis on the functional aspect

The admission of all children within the age range 6-14 years to our Basic schools instead of the selected few demands greater care in the choice and arrangement of subject matter as well as in its presentation. Studies on "learning process" point out that knowledge which is usable and is put to use is more easily acquired and better retained. The syllabus of Basic mathematics, therefore, must be such as can help children to solve mathematical problems which they meet in their school and community life. So the syllabus should consist of only those items, rules, operations and concepts that directly contribute to the achievement of the above-mentioned aim. There is no place in the syllabus for far-fetched and artificial exercises and applications of mathematical rules to unrealistic and imaginary problems which have no relevance to the children's experiences. This principle when applied to the syllabus will do away with all non-functional material that continues to dominate the field of mathematics by force of tradition and by a blind faith in the dubious psychology of mental discipline. Thus odd exercises in common fraction, absurd problems on time and work, ridiculous questions about pipes and cisterns, meaningless drill in algebraic factors and equations of higher degrees, etc., must be discarded in Basic mathematics. Mathematics needed for craft work, social and recreational activities, and community life is all that is of functional importance to children in a Basic school. There-

fore, this is what should constitute the syllabus of Basic mathematics.

Geometry in Basic mathematics

It is obvious that in a programme of Basic mathematics as indicated above, arithmetic of daily use will occupy a prominent place. Now the question arises as to whether geometry and algebra would have any place in it.

In order to answer this question, it is necessary, in the first place, to correct the prevalent false notions about geometry and algebra. People generally believe that geometry is a logical series of demonstrations as propounded by Euclid. We know from our experience that this particular treatment of geometry is beyond the understanding of even maturer minds. So long as we think of geometry in these terms, we cannot consider it fit material of instruction for the Basic school children. But demonstration forms just a small part of geometry. There are several geometrical facts which can be of immense interest and use to children in the Basic school. These facts would make their craft work more meaningful and their experiences about space richer. Practical geometry would lead them into the fields of design and art, help them to represent things by drawings and make them acquainted with measurements, direct and indirect—things which are indispensable for an intelligent practice of any productive work and for effective living. Therefore Basic mathematics must include practical geometry which is needed for carrying out craft work and other activities more efficiently. For example, in cardboard modelling various kinds of geometrical forms, e.g. circle, triangle, square, rectangle, cylinder, regular polygons, etc. have to be constructed, and in agriculture, areas and volume of various kinds of geometrical figures have to be calculated.

Thus the geometrical knowledge involved in different activities can be gained in a meaningful way in the Basic school.

Algebra in Basic mathematics

When we recall the obstacles we met in our own initial study of algebra, it is quite likely that we may discard the idea of introducing algebra in the Basic curriculum. The algebra we studied did not mean much to us in terms of its utility. It had nothing in common with our experiences in life. It dealt in mysterious symbols and generalizations, too difficult to understand, in X's, Y's and *n*th power, and in long expressions and operations none of which appeared to have much significance to us.

But algebra can also be made interesting and useful, if we adopt a right approach to it. We can profitably include that algebra which helps in solving certain arithmetical problems more easily. The formula and the equation, which are for children, the most useful parts of algebra, must be given first place and technical manipulation or fundamental rules and operations should not be introduced until it is needed for solving a practical problem.

In making a decision as to what algebra is to be used in the Basic school, it may be noted that the formulas regarding areas of common figures are already included in arithmetic, as they are found useful in cardboard modelling, woodwork and gardening. Similarly simple equations help in solving certain practical problems in craft work. Moreover, the common use of the formula and the equation in the technical and scientific world justifies the claim that a working knowledge of these two tools of algebra has a cultural value which cannot be minimized in the present civilization. On the other hand, to teach in the Basic school, the old formal algebra is worse than to teach no algebra at all.

III. Method of Teaching

Felt need, the basis of method

The preceding discussion points to the general method of teaching mathematics in the Basic school, that is, the teaching must be based on a felt need. Suppose children have spun a certain quantity of yarn out of a given quantity of cotton, and they want to find out the wastage involved in the process. Here is a situation in which children feel a need to learn the necessary arithmetical operations. Therefore those operations must be introduced on that occasion. If children are confronted with a problem or a situation which demands understanding of a particular item of mathematics, that item must be taken up. For, then, children will have a genuine interest in the material to be learnt and will make every effort needed to master it.

The teaching of new facts and mechanical operations should be presented in problem situations which require a knowledge of the new fact or operation for their solution. These problem situations should be real enough to make the child feel a need to solve them.

The teacher in a Basic school need not go out of his way in search of such situations. They are present almost at every step in the craft work, and other school programmes. Children are naturally interested in solving these problems, for they come to realize that they otherwise cannot proceed further with their work. A child who wants to make a tray out of a piece of cardboard or wood feels the need to learn the units of linear and angular measurement. Similarly, a child interested in his progress in spinning cannot do without learning to add and to subtract. The teacher would find no difficulty in exploiting such real situations

that crafts abound in for teaching almost all the rules and operations of mathematics.

Inductive versus deductive method

As to the general method of approach the teacher should adopt the inductive method to start with. For children are not generally mature enough to follow deductive procedure, which depends on rigid logical reasoning. Experience has shown that much time and energy are wasted by insisting that the child must grasp the why and wherefore of every step in an operation from the very beginning.

Inductive method, on the other hand, facilitates the learning process. After the child has been confronted with a real problem, he should be helped to reach a practical solution and convinced of its correctness through verification. For instance, in teaching addition sums which involve carrying figures the following procedure will prove successful :

Suppose a child on a particular day has spun 29 rounds of yarn ; and the next day 35 rounds. Now he wants to find out how much yarn he has spun in two days.

What the teacher has to do in this situation is to show the child the way to solve the problem. That is, after eliciting from the child that $9 + 5 = 14$, the teacher should tell him that out of 14, '4' is to be placed in the units column and 1 to be carried over to the tens and added to the figures in the tens column. Hence the tens column will have $1 + 2 + 3 = 6$, thus making the total sum equal to 64.

Then the child should be asked to verify the correctness of the answer by counting actually the number of rounds.

Now the child should be assigned similar problems from his own record of spinning, so that he may have necessary practice in solving sums that entail carrying of figures.

But the suggestion to use the inductive method should not be taken to mean that the deductive method is always to be avoided. It is profitable to learn rules, but the reason for them must be comprehended at some stage.

Therefore, the teacher should use both the methods. While following the inductive method, he should not withhold deductive explanations from those who can appreciate them. He should bear in mind that as the child advances, he grows intellectually maturer, and that he becomes competent to understand and to discover the rationale or a logical proof on which a particular operation is based. In such a case, the deductive method must be used.

Technique of correlation

In order to make an acquired item of knowledge effective, it should be related to other relevant experiences of the learner. This is known as "correlation" in educational terminology. The importance of correlation in teaching seems to be so evident that it does not need any elaboration. But unhappily this term has been so much misused and misunderstood, that perhaps there is no other issue as much confused in Basic Education as the problem of correlation. It is not necessary to go into the causes of this state of affairs here. However, the following lines are meant to clarify the meaning of correlation as applied to the teaching of Basic mathematics.

Correlation implies the integration of all related experiences. This is the natural and usual way of learning in life. Even in ordinary schools good teachers always use the technique of correlation in associating new experiences with old ones to facilitate and strengthen new learning. The Basic school offers better opportunities for doing so by providing crafts and other activities in which

children are naturally interested and which are rich in educational possibilities.

A craft or an activity can be treated as a centre of correlation in two ways :—

1. Directly i.e. certain knowledge and skill pertaining to different subjects may be needed in carrying out the various processes of the craft or the activity concerned. Acquiring that knowledge and skill in such a real situation is based on direct correlation with the craft or the activity.
2. Indirectly i.e. though an item of knowledge or skill may not be indispensable to learning any craft process or activity, it may enrich the experience of the child all the same. Imparting such an item is, therefore, indirectly correlated with the craft or the activity.

Now a few examples will be given to illustrate both kinds of correlation and to show the procedure that may be adopted in teaching certain items of mathematics.

Teaching of Subtraction

Grade II

Situation : Keeping of Daily Spinning Record.

Known : Number of slivers made ; number of slivers left after spinning.

To find out : How many slivers have been used ? (Direct correlation). If both numbers are less than 10, the children will easily find out the answer, for they are supposed to have mastered this stage of subtraction in the previous grade. But if either of the numbers is greater than 10, a new problem would arise for which the children are not expected to have a ready-made response.

Examples :—

Suppose some of the entries from the children's record are as follows :

	Sliver made	Sliver remained
1.	14	2
2.	26	14
3.	16	8
4.	21	12

Stage I: Sums involving no carrying figure.

A. One of the numbers is greater than 10, and the other less than 10 (Example 1). Take similar problems from the actual record of the children or from their other activities e.g. games, sports, gardening etc.

B. Both numbers are greater than 10 (Example 2).

Stage II: Sums involving carrying figure.

A. One of the numbers is greater than 10, and the other less than 10 (Example 3). Use this situation to introduce further subtraction tables. Make children learn them by heart through repetition, games, flash cards, self-directive material etc.

B. Both numbers are composed of two digits (Example 4). Besides the problems connected with crafts other problems relating to the home and community life should be assigned for practice.

Stage III: Numbers up to three digits.

Teaching of compound addition

Grade IV :

Situation (1) : Calculating the monthly income from craft work.

Known : Daily income from the individual craft work calculated by the teacher.

To find out : The total income for the whole month (Direct correlation).

Stage I : Mutual conversion of currency units.

Stage II : Addition.

Situation (2) : Calculating the actual expenditure on craft work recurring and non-recurring for the whole school.

Known : Cost of different articles used in craft work supplied by the teacher.

To find out : The total expenditure (Indirect correlation, for this problem does not occur to the children during their craft work).

Such problems not only serve as appropriate exercises in compound addition, but also make craft work more meaningful to the child and enrich his experience.

Teaching to calculate the volume of a cube

Grade VI :

Situation : Planning to make a table from wood.

Given : Measurements of the various parts of the table.

To find out : The timber needed for it (Direct correlation with woodwork).

Stage I : Concept of volume, distinguishing it from surface or area. Unit of volume.

Stage II : Rule for finding out the volume of a cube or cuboid (by cutting it into unit cubes).

For the application of this principle, exercises from masonry may profitably be assigned. For example, children may be asked to calculate the cost of the bricks needed in building a house of specified dimensions, the size of the brick and its cost price being given.

IV. Drill and Review

In spite of the fact that there is no lack of real situations for teaching mathematics in a Basic school, acquisition of the skills needed for success in the subject will consume a good deal of labour and time. One cannot expect to achieve speed and accuracy in solving arithmetical problems that occur in day-to-day life without having a full command of the basic facts and operations of arithmetic. They have to be learnt by heart through sufficient drill and practice. The teacher should see to it that the responses of children with regard to the basic facts i.e. numbers and tables are made mechanical, though the task of memorizing should not be performed mechanically but with understanding.

The teacher should guard against the situation in which children make correct responses automatically without a proper understanding of the numbers and of the processes. The lack of adequate concepts at various grade levels indicates that sufficient attention has not been paid to the engendering of meaning. The teacher often fails to realize what is involved in the acquisition of number concepts and to recognize that verbal counting and similar performances should not be taken as a reliable criterion of the acquisition of the corresponding concepts. He must, therefore, emphasize understanding of number and its various processes, especially during the early stages of acquiring skill in calculation.

Criteria for drill

1. Drill for creating a high level of a skill can only be justified by the frequency of use of that skill in life. For example, drill in the multiplication table of 12 and 16 is essential, as these tables are used again and again in solving day-to-day problems involving money, weight, and linear measurements. On the other hand, drill in multiplication tables of 13 or 14 cannot be justified, because these tables are not frequently used in our life.

2. The drill load must be light enough to make success possible, as drill is a very tiresome activity.

3. The drill must result in a perfect score. The purpose of drill is mastery. One should not be, therefore, satisfied with a low standard of achievement. The most useful processes must be fully mastered and retained.

How to motivate drill?

One of the important factors that determine the efficacy of drill and practice is motivation. Much of the unmotivated practice is worse than useless.

The teacher should always remember that the whole motivational setting is more important than isolated attempts to stimulate learning. The whole life in the school should be organized in such a way as to make the learning process natural and worthwhile for children. This can happen only when children's needs for affiliation and for approval are duly taken care of by providing them opportunities to participate in group life and to receive recognition for what they do. Fortunately, it is easier to create such an environment in the Basic school, where craft and other social activities present ample opportunities for group participation and personal recognition.

Given the general motivational setting in the school, a child can be stimulated to learn a certain fact or operation, if its meaning and relationship with his other activities are made clear to him. For instance, children who are engaged in growing vegetables in the school garden, must sell the produce. This situation can be used to induce them to learn multiplication tables. The meaning of these tables can be easily brought home to the children, if a vegetable shop is run as a project in the school.

Meaningful material is learnt more quickly and with less effort than material which has no meaning. Therefore, the child should be made to understand the why of everything, he is required to learn or memorize.

Informing children of their success in learning by appropriate tests also makes for motivation. For the knowledge of success serves as a very good incentive for further efforts.

The teacher can help maintain the success experience of children by capitalizing upon the subgoals along the way and by avoiding so narrow a definition of goals that are attainable by only a few. Every child should feel that there is a goal of improvement open to him. It is neither desirable nor useful to create a spirit of competition among children, for it may degenerate into selfishness, over-anxiety, etc., instead of serving as a means of positive motivation. The teacher should see to it that a proper balance is maintained between the task assigned to a child and his capacity to perform it. In drill work, this is particularly needed.

How to make drill effective?

Drill is useful when children individually engage in practice to correct a specific error. Group drill should be considered wasteful of time and energy, because many children may not need it. However, on occasions, when a certain

error is found to be very frequent among children, group drill can fruitfully be organized.

Attentive repetitions are necessary to fix the associations in learning the tables. These repetitions may be given either in isolated drill or in the use of these number facts in the doing of examples.

The teacher should guard against the danger of over-learning. It is often felt that children are compelled to continue repeating and memorizing addition, subtraction and multiplication tables etc, beyond the attainment of a reasonable criterion. Thus much time and energy are spent for nothing. Moderate initial practice and systematic review are superior to over-learning.

Drill periods should be short, say, from 10 to 15 minutes, as the monotony involved in the drill work produces undue nervous strain, and consequently a loss of interest.

After a fact or principle has been learnt, it needs to be repeated from time to time. At the beginning, the interval between two successive reviews should be short. As time goes on, the length of the intervals should be increased, and the duration of practice diminished. No fact or principle should ever be entirely abandoned.

A spirit of play can usefully be introduced to make the process of memorization less tiresome. This can be achieved by making use of number games, flash cards, self-directive material, etc.

After the initial stage of practice varied situations of school, home and community life should be presented to which facts and principles can be applied.

Drill should often be indirect or disguised. Very often the best way to drill is not to do ten more exercises of the same kind, but to apply the fact learnt to a new situation. This serves to take the pupil's mind off the fact that he is drilling. For example, calculating the area of the rectangle,

in connection with sowing crops in rectangular fields, will provide drill in multiplication more effectively than doing nothing but drill on multiplication. Similarly the measurement work in various crafts will probably accomplish enough improvement in computation without spending too much time on mechanical drill.

Short cuts should not be over-emphasized. No short cut should be introduced unless it is to be used repeatedly to do really useful work, and, in general short cuts should not be introduced unless they can be justified to the pupil. Multiplication and division by ten and its multiples can easily be done by a short cut. A little attention should be given to multiplication by such "relatives of ten" as five and twenty-five, and by the easy fractional parts of one hundred. The test for any short process is whether it proves really useful to the child as he proceeds, and whether it leads him to think more intelligently about numbers.

Reviews

Review or revision of learnt material at certain intervals is a common feature of teaching mathematics in our schools. At the beginning of each grade, the work of the previous grade is ceremoniously revised. But perhaps it is not the best introduction to the new grade's work. The pupil is naturally curious about what new things he is going to learn. Our failure to give him the opportunity to do so, and our attempt to initiate him into the new grade by means of reviews and drills on the old familiar things may easily damp his enthusiasm for new mathematics. It is better to introduce the new material and then blend reviews of relevant items into it, as need arises.

There is no denying the fact that reviews are needed sometimes during the year. It is generally found that certain

children in a class fail to handle the fundamental processes with accuracy and speed. This is due to a defect in the computational ability which must be remedied. For this a review is necessary. But it should be noted that a review in the higher grades of a Basic school is not the same kind of thing as a review in the lower grades, because judgment keeps on developing with age, and the review now must take advantage of this increased judgment and even aim to cause it to grow still further. Children should be helped to judge for themselves the accuracy of their own answers.

V. Individual Differences

Every teacher knows that children vary in the rate at which they learn and also in their capacity to learn. In mathematics such individual differences are more pronounced than in other subjects. Therefore, the teacher should organize his class work in accordance with these differences, so that each child may attain a measure of success in the essentials of arithmetic. The assignments should be so graded that each child at every step may experience the joy of overcoming difficulties rather than the dejection of hopeless failure. The child should be allowed to advance at his natural pace. He should neither be held back to wait for others to catch up with him, nor should he be goaded into catching up with others who are far ahead of him.

Classification of Children

The teacher is, therefore, advised to adopt the following procedure:—

New work should be taken up with the class as a whole, the quick children playing the part of explorers. Then, for the practice and drill, the class should be divided into three

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groups, say, A, B and C—the fast, average, and slow groups.

Work done by 'A' group can be marked outside the class or by each individual, or by the first children to finish the day's work, or they may be made to work in pairs and help each other. They need only occasional help in case of a hard problem and slight supervision. When they have mastered a certain process or principle, they could be assigned harder work which the other two groups should not be required to do.

The 'B' group needs considerable attention and supervision from the teacher. This group sets the standard for the class. While planning and giving a new lesson to the whole class, the teacher adopts his procedure in accordance with the level of understanding of this group.

Group 'C' requires the teacher's constant attention and care. He should divide his time evenly between groups 'B' and 'C' either by devoting most of the time to one group on one day and the other the next day, or by dividing his attention in one lesson pretty equally.

The cooperation of the best children in each group must be enlisted in helping the weaker ones, or in marking their work.

Different groups should be allotted different days for weekly lessons in pure drill work to develop speed and accuracy in fundamental operations.

There should be differences in the material assigned to these groups. The slow group is expected to cover just the minimum essentials, while the rapid group should have more difficult problems. This arrangement of providing for individual differences, however, will be found less frequently in operation in the junior grades than in the senior grades of the Basic school.

Methods of teaching should also be adopted to the abilities

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of the children in the various groups. The slow group will require explanation in the simplest and most concrete form and will need to have these explanations repeated again and again with variations in the approach and in the nature of the illustrative material. The bright group, on the other hand, will understand processes more quickly.

In teaching slow groups, it is sometimes necessary to omit the 'why' of a procedure in the beginning and to induce the children to devote themselves entirely to the 'how' of the process in order to gain skill in it. Of course, the reasons should be supplied when they have made sufficient headway in the process.

VI. Oral and Written Arithmetic

The actual work of arithmetic consists of drilling the fundamentals for the grade and solving problems based upon them. Both of these activities require oral and written practice. The recording of the result only and not the immediate steps is more important for beginners. Both oral and written practices should employ small numbers, because it is merely the process which is important and for this it is not necessary to use large numbers of which children do not have a clear concept. As a habit-forming measure both oral and written exercises, should be included in every lesson. The first five to ten minutes of every lesson may usefully be devoted to oral arithmetic. For brisk drill in specific operations and for practice in solving a wide variety of problems, children should be encouraged to use oral arithmetic. They should be so accustomed to this mental work, that in making the calculations required in craft work and a number of problems pertaining to our life, they should not stand in need of using pen or pencil.

General procedure for using both oral and written arithmetic

In order to provide for every phase of work, the arithmetic period may be divided into four parts as follows:

1. Oral fundamentals— 2. Written fundamentals — 3. Oral problems — 4. Written problems.

These exercises will expose weaknesses which may be treated as each individual teacher deems practicable.

In the formal study of the fundamentals every new concept taught to a class should be followed by appropriate oral drill. Those who were unable to understand the concept clearly in the first lesson will now receive another lesson. At no time should a child be hurried when slow, or rebuked when incorrect. The weak child should be encouraged, until he can do the example unassisted. When the drill comes to an end, the class and the teacher should decide upon the new exercise for the next lesson.

Written exercises to apply these drills in fundamentals need never be long. The traditional practice of assigning a number of lengthy sums to be completed within a short period should be discarded, because such a practice results in a number of errors due to top speed. It is better to work four examples without undue pressure than a hundred under strain.

The marking of the written work should not give the child an impression that he has been penalized or humiliated. The child may be permitted to mark his own work after the correct procedure has been demonstrated by the teacher to the whole class. Then the teacher should look the work over carefully. When the child is confident that he will not be punished, if he reports his weakness, but that everything possible will be done to assist him to overcome it, he will be as honest in his marking as the teacher would be, if he himself scored the work.

The teacher should encourage children to check up their

own work. For this, it is essential to acquaint them with the methods of finding out whether their answers are correct. For instance, children should be able to assess the accuracy of their answers to addition sums by adding them up in the reverse direction, i.e. from bottom to top. Similarly, they should know how to verify their answers to an arithmetic problem they have solved. This procedure will create self-confidence in children and provide them with more opportunities for practice in doing sums on their own. Thus they will acquire greater understanding of inter-relationship of the various arithmetic processes, and the teacher will save some of his time and energy in the bargain.

VII. Solving of Problem

The Basic school regards problem solving as the main goal of teaching arithmetic. For, what really matters for the child in arithmetic is his ability to solve problems he comes across in the pursuit of his activities both inside and outside the school. Plenty of arithmetical problems occur in an average Basic school where buying of craft material and selling of craft produce, and keeping of the record of work form an integral part of education. Besides these problems the child finds similar ones in his home where transactions of buying and selling, borrowing and lending etc. are normal events. The child should, therefore, have enough practice in solving such problems with accuracy and speed.

Difference between "problem" and "example"

Problems arise out of concrete situations. Examples are pure abstractions, e.g. $5 + 3 = ?$, $9 - 4 = ?$, etc. Arithmetic which arises out of activities in which children engage themselves is problem arithmetic. The solution of a problem requires

undoubtedly the solution of an example, but the problem is the main thing. A child who has already spun 95 rounds of yarn faces a problem to solve, if he wants to know how many more rounds of yarn he should spin to complete a *latti* of 160 rounds. In order to solve this problem, he must understand which operation is involved in it. When he decides that subtraction should be applied to solve the problem, it boils down to an example.

It is clear that the problem is likely to be more interesting and more meaningful to children than the example. Children who are held for long on a programme of example solving are almost certain to lose interest in arithmetic. When, on the contrary, they solve problems, specially those problems which arise out of their own activities., e.g., craft work, celebration of festivals and important days, excursions etc., they find their arithmetic to be a vital and functioning thing.

In every arithmetic text-book, there are given a number of 'problems'. But those exercises cannot be regarded as problems, unless they are accepted by the pupil as such. Only in so far as his purposes and objectives are involved, does an exercise become a problem to him. If the exercise is related to his experiences and activities, it is more likely accepted as a worthwhile problem and he would, then, direct his efforts towards formulating a solution.

Characteristics of good problems

In selecting problems for children to solve, the teacher should keep in mind the main characteristics of a good problem which are as follows:

1. *Reality*. Good problems are real. They deal with children's own experiences, or the experiences of others in whom the children are interested.

2. *Interest.* Good problems are interesting. They are related to situations which are not only real but which make a strong appeal to the children.

3. *Language.* Good problems are stated in a language which children can easily understand. They are free from unknown words and unfamiliar forms of expression. Problems should be presented in an attractive style.

4. *Use of basic skills.* Good problems demand the use of fundamental skills. They are closely related to the scheme of lessons on the fundamental operations.

How to improve the ability of problem solving?

Children must have command of the requisite arithmetic concepts and skills, before they are required to solve quantitative problems. The usefulness and availability of knowledges and skills for application to a problem situation depend, however, upon the manner in which those knowledges and skills were learned by children. Experience has shown that mechanical drill of arithmetic processes with emphasis on automatic response does not make for correct application of the processes concerned in a new situation. But, if the meaning of the processes has been emphasized during the course of learning, they can be easily used in solving a new problem.

When a problem arises in course of an activity which is worthy of the attention of the class, the teacher should resist the temptation of giving the solution himself. He should, on the other hand, encourage the children to explore the problem fully without exerting pressure on them for a quick answer. He should guide them in the systematic and organized statement of the problem with all its relevant information. Suppose, for example, a class has finished a cardboard

model, say, a tray. Now a problem arises as to what should be the sale price of the tray. For this, the children will have to find the necessary data, i.e. the cost of the cardboard, paper, colours, etc. and the rate of profit proposed to be made on the finished articles. Then the teacher would guide them to find out the solution of the problem through proper questions.

In order to make children competent to solve problems, it will not suffice to confine them to solving only the real problems which occur in the craft work and other school activities. For this purpose, problems assigned by the teacher from arithmetic books will also have to be used. The teacher should, however, select only those problems which he can reasonably expect the children to solve, because they prefer the kinds of problems which they believe they can solve.

On reading a problem, children should try to clarify its meaning, before giving any consideration to the processes to be used in the given problem. Children should be trained to read and understand the problem correctly and to analyse it to know what is given and what is to be found out. Then they should think out the processes to use in solving the problem.

Definite training in reading and analysing problems should receive ample attention. The oral discussion of the problems should, therefore, form a regular feature of class work and children should have frequent opportunities to state the solution, step by step, with and without mental calculations.

When a problem has been analysed in detail and relevant information gathered, it sometimes helps to put the problem away for a while. By doing so, the child may get free from false assumptions and unsuitable methods of attack which suggest themselves all at once, and he may be in a better position to try new variations of methods that are probably more helpful. The role of time for the maturing

of hypothesis needs recognition by teachers. Children should not be forced to adopt a premature solution of a given problem.

In clarifying a problem, it helps to reduce the number in the example to the realm of the pupil's experience or to dramatise the example. Whenever a problem seems difficult, volunteers can be called for, to become shopkeeper and customer, or other persons mentioned in the example. Their transaction becomes a reality which helps to determine two facts : the method of solving the example and the answer in words. The actual working of the problem is of less importance than its interpretation.

After a certain type of problem has been analysed and the teacher is assured that the class understands what to do, there should be plenty of opportunity for practice.

Sources of problem material

Of all the material at the teacher's command, the utilization of the children's current interests and experiences will do most toward making the problem vital. Children may be asked to extract necessary data for problems from their own record of craft work, or for the sake of systematic and graded practice the teacher should supply the requisite data. But the data must always be realistic and meaningful to the children.

An excellent source of problem material is to be found in tables of measurement. In the Basic school, children have actually to deal with measures of length, weight, time and even money in their craft work.

The choice of problem material will help or hinder the pupil's ability to understand. Frequently text-book examples and examples given by the teacher are so far removed from children's daily experiences that even the vocabulary of

the problem is strange. That is why children often do not happily take to problem solving. But when arithmetic problems are related to children's life, they become meaningful and interesting.

Factors in problem solving

In all work a premium should be placed both on clarity of thought and accuracy in computation. Clarity of thought depends largely on the child's comprehension of the conditions or data given in the problem. Therefore, if the data are related to the child's own experience, clarity of thought can be ensured.

Accuracy in computation depends not only on the child's competence in the fundamental operations, but also on the neatness and orderliness with which the work is set down. The teacher should not, therefore, accept unsystematic and slovenly work under any circumstances. A habit which greatly contributes to accuracy is to make an estimate of the answer before carrying out computation and to check the result in the end. This habit should, therefore, be systematically cultivated.

To sum up, in guiding children to solve problems the teacher should follow the procedure given below :—

Help children to state the problem clearly and analyse it correctly. Encourage them to make their suggestions regarding its solution. Get them to evaluate each suggestion. This involves examining a suggestion critically, whether it would lead to the correct solution, and verifying the result.

Have them organize their process of solution by drawing an outline of the steps they would take to arrive at the answer.

Make them work out the problem according to the outline.

Ask them to check up the answer.

Make them do some more problems of the same type.

VIII. Evaluation and Tests

THERE is no place for the usual type of external examinations in the scheme of Basic Education. But it does not mean that tests should altogether be abolished in the Basic school. There must be some way to evaluate pupil achievement. It is necessary for the teacher to evaluate the work of his pupils by means of suitable tests at frequent intervals in order to determine whether they have acquired the necessary skills and discover where their difficulties lie. On the basis of such tests he can modify, if necessary, his teaching or plan remedial exercises for individual children.

Oral and written tests

In the first grade the tests should mostly be oral. The teacher, as he works with the pupils on the elements of arithmetic, should make mental and written notes of what they as individuals can and cannot do and of what they know and do not know. But after the pupils have learnt to read and write numbers, after they have achieved a fair degree of proficiency with the fundamental operations, written tests can be used more profitably.

Elements to be evaluated

In performing the fundamental operations in arithmetic, two objectives are kept in view :—"Skill" and "power." Skill refers to the speed and accuracy of performing the

operation. In a test that involves skill the factors of time and number of operations that are correctly done are most important. On the other hand, if we wish to know how difficult a problem a pupil can do, a power test is used. In a power test, therefore, items go on increasing in difficulty, while in a skill test all the items are almost of equal difficulty.

In addition to the two types of tests mentioned above, we need tests which can assess the reasoning ability. Tests of this kind are based on the ability of the pupil to formulate a correct plan for the solution of a problem. In such tests the accuracy of the plan formulated is of more importance than the speed of formulating the plan or that of computing the result.

In measuring the achievement in arithmetic, it is necessary to have definitely in mind the purpose of testing. If the teacher merely wishes to measure achievement, a general test in the fundamentals will be sufficient. But if he is concerned with the details of the instruction and the further needs of his pupils, he must have specific information as to the types of examples the pupils can do with ease and confidence and the types they cannot do. In this case a more elaborate test is needed in order to find the real nature of the pupil's weaknesses so that the instruction may be stepped up to rectify them. It is here that diagnostic tests are very valuable.

Diagnostic tests

In arithmetic, it is indispensable to diagnose individual difficulties and to formulate a suitable remedial programme. For, arithmetic is a subject in which every new step depends entirely on the preceding one. A child who has not mastered a particular operation becomes more and more confused

and dejected as he proceeds, unless his previous difficulties are cleared up. Every teacher should, therefore, accept the responsibility of seeing that children understand what precedes before new work is undertaken.

In order to make a diagnostic test on a particular operation, the teacher must, in the first place, make a detailed analysis of the various steps involved in that operation and then set suitable items corresponding to each one of those steps.

After the test has been administered to the class, the test papers should be analyzed minutely and the specific items missed by each pupil should be discovered. In addition to the types of errors, the teacher should study each child's habits of work individually in order to gain insight into his mental processes .Occasionally the teacher should watch the pupil, as he proceeds with a certain operation and says aloud what he thinks. An oral performance of a calculation may reveal difficulties or wasteful procedures not apparent from a test paper. When specific weaknesses and their causes are, thus identified, suitable practice material should be provided as a remedial measure.

Remedial Work

After discovering the exact nature of individual pupil's weaknesses, the teacher would precisely know what type of practice each pupil needs. He should then prepare assignments for each containing several examples. The remedial work should continue until the specific weakness has been overcome or until the pupil passes the next diagnostic test.

This procedure of remedial work is useful not only in the case of fundamental operations, but also in problem solving. Some children fail here because of reading disabilities, some

through carelessness in computation, some because they trust to memorised solutions, and many through lack of reasoning ability. In every case the teacher should seek sympathetically but earnestly to discover the cause of failure, and take the necessary steps to remove it, so that each child may have the joy of success in solving problems up to the limit of his capacity.

IX. MATHEMATICS TEXT-BOOK

Place of books in Basic Education

WHAT is the place of books in Basic Education?

This has been a controversial issue ever since the inception of the scheme of Basic Education. Some of the authors of the scheme strongly believe that the introduction of books in the Basic school will pave the way for its degeneration into a "book school" where book cramming is the be-all and end-all of education.

But by and by a considerable section of workers in the field of Basic Education has come to realize the need for suitable books both for teachers and children of Basic schools. Even these people are, however, aware of the danger inherent in the book education and this is why they suggest that books should be regarded only as a supplementary material to learning through experience and not as a substitute for education. Based on this principle a text-book in mathematics would seek to strengthen the skills in computation and problem solving acquired in craft work and other activities.

CHARACTERISTICS OF A GOOD TEXT-BOOK IN MATHEMATICS

1. *Functional aspect of arithmetic*

The material given in the book should be related to the

real needs of the class for which the book is meant. The problems should centre around the various processes involved in craft work and other social activities of children inside and outside the school. Thus the book will include only those elements of knowledge and skills which are of most use in the day-to-day life of the children and the community. There should be ample material for practice of those rules and operations which are needed to solve numerical problems met with in actual life situations. The material which is exclusively meant for "mental gymnastics" should have no place in a Basic mathematics book. For instance, exercises on continued fractions, English coins, prime numbers and factors, H.C.F. and L.C.M., problems on garrisons and prisoners, pipes and cisterns, clocks etc. which the traditional text-books abound in must be discarded, because drilling on such exercises and problems does not serve any useful purpose in the life of our children. The functional aspect of mathematics is, therefore, to be emphasized throughout a text-book.

2. *Concreteness of subject matter*

The material included in a book should be presented concretely, so that children may grasp it easily. Rules and principles should not be given as abstract formulations. Rather, they should be derived by the children themselves on the basis of their own experiences. Illustrations, both pictorial and graphic, should be inserted to make concepts vivid and meaningful.

Examples should be drawn from life situations. If they are based on statistical figures concerning our population, agriculture, industry, commerce, social services and the like, they would not only give a realistic touch to the arithmetic work in our schools, but they would help to broaden the

horizon of children's understanding of our social and national problems.

On the other hand, problems that are divorced from life, must be avoided. In the current text-books of arithmetic one often comes across absurd problems based on unrealistic and ridiculous data. For instance, cost of articles given may bear no relation to their actual cost, dimensions and specifications of things described may be altogether fictitious, and so on. This makes arithmetic unreal and abstract to many children and they feel no interest in it.

3. *Gradation in difficulty*

The principles of graded difficulty should be observed in arranging the subject matter of the book, so that the child may achieve mastery over it by easy steps meeting easier problems in the beginning and more and more difficult ones later on as he goes on gaining greater competence and more self-confidence. At any stage the problems presented should neither be so difficult as to frustrate the child by frequent failures, nor so easy that he may get bored by easy success. The problems should be so graded in difficulty that they offer a challenge to his powers and that he can achieve success with effort. Nothing succeeds like success. So success achieved at one stage will goad him to put in greater effort to achieve success at the subsequent stage.

4. *Use of motivation*

In order to introduce a new item or rule, it is essential to establish a suitable learning situation. Every new item should be built on the sure foundation of a felt need. It should evolve out of the preceding one in a natural way.

Suppose, a child is practising a certain rule or operation and while doing so he is confronted with a problem involving a new concept with which he is not so far familiar. This is a situation which is very appropriate for introducing that concept. The child feels an actual need to learn it, as he realizes that unless he learns it, he cannot solve that problem.

5. *Analysis of examples*

An arithmetic book for children need not contain solved examples. After the children have learnt a rule or operation in the class from their teacher, there is no need for its discussion or demonstration in the text-book. All that is needed is to provide the children with graded sets of exercises for additional practice and these should be given in the book. If solved examples are given in the book, the stress should be laid on the analysis of the problems and not on the mechanical aspect of so called "model solution." This analysis of the problem should enable the children to understand the bonds between that which is given and that which is to be found out. The value of analysis lies in its clearness and conciseness.

6. *Mental arithmetic*

The book should contain mental exercises in addition to the written ones. Mental arithmetic should be regarded an essential part of education for citizenship and effective living. Daily life situations make the demand for mental arithmetic imperative. We often have to make mental computations in our day-to-day transactions in the home and market-place. Mental arithmetic should, therefore, find an important place in the text-books of all grades.

PART II

TEACHING SPECIFIC UNITS

X. Number

Number concept is the most fundamental thing in arithmetic. In teaching it, purposeful experience with concrete objects should be provided. This principle is often misunderstood in practice. In so called 'Modern' or even Basic schools children are made to count marbles, splints, taklis, winders etc. and measure tables, rooms and so on with a view to teaching them number. But this does not signify any purposeful experience. For, an experience is purposeful only when it is acquired in response to a need or purpose, which the child conceives as real. For instance, when a child wants to record his performance in craft, he feels the need to count the rounds of yarn spun, the number of slivers made, saplings planted or to measure the dimensions of the flower-beds prepared and so on. Counting or measuring in such situations provides him purposeful experience, as it is in response to a need he has genuinely felt. Unhappily our schools do not generally realize the importance of this sound principle. There is too much of rote counting done parrot-like by our children. They learn to recite the number words by sheer repetition without reference to objective experience. Rote counting, if permitted to run ahead of number understanding, becomes a meaningless practice. It must, therefore, be avoided.

Stages of number concept

Number concept should be strengthened by leading the child gradually through the following stages :—

1. The object stage : purely concrete numbers.
2. The picture stage : pictures of familiar objects.
3. The semi-concrete number stage : dots, lines, circles, etc.
4. The abstract number stage : number symbols.

The object stage

The Basic school offers many opportunities for experiencing with concrete numbers. In the first grade when the child begins spinning, he counts slivers, taklis, winders, etc. while distributing them among his classmates. He counts the rounds of yarn while winding it on the winder. He weighs the cotton taken for ginning and carding, and vegetables produced in the school garden. He finds out his own weight and that of other children at the end of every month. He measures his height and chest every six months. In games he counts the number of children needed. He experiments with time measures, e.g. hour, minute, day, week, month, etc., while recording the amount of craft work done during a given period. He handles small sums of money while selling the produce of his vegetable garden. Thus he has varied purposeful experiences with concrete numbers.

The picture stage

As the child makes progress with the member concept, he should develop the ability to perform number activities without the help of concrete objects. But the child should be helped to pass from the object stage to the abstract number stage gradually by easy steps. The object stage leads conveniently to the picture stage as a first step from concrete number towards abstract number. Pictorial num-

ber charts and illustrated number books should be used at the second stage. Pictures have an advantage over the actual objects in that they are easily handled and in that a much wider variety is possible. Pictures should, however, be attractive to children. So coloured pictures are preferable to plain black and white ones.

The semi-concrete stage

Number representations in the form of circles, lines, dots and the like signify still a greater advance in the direction of abstract number. Such representations are concrete but not to the same extent as pictures of familiar objects are concrete.

The abstract symbol stage

The stage is reached only after a good deal of experience in the foregoing stages and after considerable time. Children learn what *five* means and they use the word "five" orally long before they learn to read the symbol "5". But eventually the symbol "5" must be recognized and associated with the concept of "five".

Counting by multiples

When the child has become proficient in counting by 1's, he should be introduced to counting by multiples, as it would save his time and increase his understanding of number. It is a common practice in our day-to-day life to count by 2's, 4's and 5's. The child should be motivated to adopt this practice gradually through the same stages which were gone through while learning to count by 1's. To begin with, he should be taught to count the rounds of yarn on the winder by picking them up two at a time and

say two, four, six, eight, etc. Then for the sake of drill he could be given such material as pictures of children marching in twos, circles and dots in pairs, etc., until he arrives at the abstract stage and is able to do rote counting by twos.

It is more difficult to carry out counting by 4's and 5's with concrete objects. Small objects like seeds can be placed in groups of four or five each and then counted four, eight, twelve, etc., or five, ten, fifteen and so on. The number of pice in a given number of one-anna pieces can be determined in the same way, but this is more abstract, as the pice are not actually present.

Abstract counting by 5's and 10's, particularly 10's, up to 100 helps to clarify and strengthen the concept that our number is based on the decimal system. The child must see the relationship of "twenty" to "two", or "thirty" to "three" and so on.

Reading and writing numbers

After children have acquired a rich and extensive experience with numbers, they should learn to read the number symbols which represent in an abstract way the numbers they come to know in concrete and semi-concrete situations. In a Basic school the need to read and write numbers arises rather earlier, when children begin to produce something in their craft work and want to enter it on their record card.

Teachers should at this stage familiarize children with symbols 1 to 9 inclusive. This is difficult and requires more time than is generally devoted to it. Number symbols must be taken up slowly, one at a time, and sufficient practice on each provided to enable children to remember it.

It is not advisable to begin with 0. The symbol 0 should be introduced only when a real and meaningful situation

requiring the use of this symbol arises. This may be used in keeping record of craft work when a child has produced nothing or in keeping score in games when he has made no point at a trial.

After children have learned to read the numbers 1 to 9, and after they have had experiences with larger numbers, 10 to 19 should be taught. Association with the single digits would help here. Thus the number 16 contains 1 and 6, with which children are already familiar. Here it must be made clear that in 16, the 1 is in ten's place and is, therefore, equal to ten (10). The device of using splints in bundles of ten and singly would help here.

The fact that our number is based on the decimal system helps greatly as we go from one decade to another. There should be no difficulty in making children familiar with numbers up to 99. The teacher should prepare a number table and write it in neat and orderly fashion on a chart in ten columns decade-wise. A similar procedure should be adopted with regard to three-digit numbers.

While children are learning to write numbers, the teacher should be very careful about the manner they form the figures. If left to themselves children are liable to invent peculiar ways to form the figures and thus they would fail to use the economical movements which should necessarily be employed. The teacher must, therefore, closely supervise individual children, as they learn to form these figures.

Practice in reading and writing numbers

Children should not be asked to read and write very large numbers which are beyond their comprehension. The maxim, "Educate the children with numbers in children's size" represents a sound principle of education. This does not, however, mean that the child is not to have a little

experience with large numbers, such as he sees in the newspapers and wants to read them; but that the numbers which he comes across in his day-to-day life are of modest size. The task of making numbers real to the child can be performed only when they are connected with his experience. Numbers which arise from his own performance in craft, or from situations which are real to him, are much more likely to take on real size in his mind than are large numbers which look to him like strings of digits only.

XI. Four Fundamental Rules

Understanding and using the four fundamental rules, viz. addition, subtraction, multiplication and division are basic to learning arithmetic. Acquisition of adequate skill in these operations needs a great deal of practice.

In a Basic school children begin to feel the need to learn these operations rather early. In the craft work, when they have to record and evaluate their performance in terms of its quantity and quality, and compute the value of their produce they would need a knowledge of all fundamental rules.

How to begin the work in addition ?

The ability to count should be well developed in children before instruction in addition is begun. Suppose the children can count the slivers provided them by their teacher at different intervals. Then they may be induced to find the total number of slivers used during the spinning period. This would involve the operation of addition.

The Basic combinations

After the children have realized the need to learn addition,

they should be led to understand the basic combinations or bonds.

There are 100 such combinations in all including the zero combinations. Children should be made to understand the meaning of these combinations by manipulating concrete objects such as splints, marbles, etc. Teaching of zero combinations should, however, be postponed till situations involving their use arise. For instance, when children come across such examples as 30+5, 120+47, 118+201, 50+30, etc. Then is the time to teach that *any number plus zero equals the number, and zero plus any number equals the number*.

In teaching combinations the following plan can profitably be followed :—

1. Divide the combinations into two groups, putting those whose sums are 10 or less than 10 into the easier group and the remaining into the harder group.
2. In teaching a combination, use its reverse form simultaneously. For instance, 7+1, should be followed by 1+7.

There are many devices which can help fix these combinations in children's minds so as to make their responses automatic. Flash cards, self-directive cards, games and the like are generally employed for this purpose.

Subtraction

Situations similar to those indicated in connection with addition can be utilized for teaching subtraction. Like addition, subtraction should begin with basic combinations. The subtraction facts can profitably be presented along with

the corresponding addition facts, making a teaching unit of the four facts (two in the case of a double), e.g. $7+1=8$, $8-7=1$; $1+7=8$, $8-1=7$.

Steps in subtraction

1. The first examples in subtraction, beyond the basic facts, would be simple subtraction without borrowing. At first the examples should be made up of two-digit numbers only.

2. Then such examples as need borrowing should be taken. Suppose a child spins 45 rounds of yarn in the spinning period on a particular day and the day before he has spun 38 rounds of yarn. He wants to find out what progress he has made. Here he has to subtract 38 from 45. This would need decomposing or breaking up a ten into 10 units.

3. As soon as the meaning of the borrowing operation has been made clear and the child has attained some competence in the process, he should be shown how to shorten the process. The teacher should spend some time with the children individually to discover how they subtract and to help them establish good habits. Suppose the child who has already spun 487 rounds of yarn wants to find out how much more yarn he should spin in order to complete a *gundi* (640 rounds of yarn). While subtracting 487 from 640, the child should think merely "7 from 10, 3 ; 8 from 13, 5 ; 4 from 5, 1", as he writes the digits of the answer from right to left. Of course, this high level of competence can be gained only after considerable practice.

Multiplication

There are several points of similarity between the plans

for teaching multiplication and addition. The concept of multiplication must be made clear by introducing it as a shorter method for addition, if the addends are equal. In teaching multiplication the first step is to make the children understand and memorize the multiplication combinations. There are 100 basic combinations, the same that constitute the usual multiplication tables up to 10×10. But in our country, while dealing with the measures of length, weight, time and money, we have to use frequently the multiplication tables of 12 and 16 (one foot=12 inches ; one seer=16 chatanks ; one year=12 months ; one rupee=16 annas ; one anna=12 pies). It is, therefore, necessary that children learn the tables of 12×10 and 16×10 in addition to the above-mentioned 100 combinations.

Steps in multiplication

1. After the basic multiplication facts have been learnt by the children, multiplication examples without carrying figures can be taken up. In the beginning the work should be limited to one-digit multipliers and two-digit multiplicands, e.g. 11×2, 34×2, 33×3, 22×4, etc.

2. Then the examples involving carrying figures can be considered. Since carrying in addition has already been taught, there should be no serious difficulty in getting the children see the meaning of carrying figures in multiplication. But at this stage, the examples must be limited to one-digit multipliers and two-digit or three-digit multiplicands.

3. The above step should be followed by examples involving two-digit multipliers which have one-digit factors, e.g. $18=2 \times 9$; $24=3 \times 8$, etc. By these examples, the method of multiplication by factors must be made clear. The children should then be assigned such examples as have

for their multipliers, the multiples of 10, e.g. 20, 30, 40, etc.

4. Lastly the method of long multiplication should be taught. The children should be made to understand its rationale by showing that the multiplication becomes easier, if the multiplier is broken up into two parts—a multiple of 10 and a one-digit number. For instance, in multiplying a number say, 125 by 23, the multiplier should be broken up into 20+3. Then the number 125 should be multiplied first by 20 and then by 3 and finally the two products thus obtained should be added up to give the required answer.

Division

The basic facts of division and those of multiplication should be taught together, because first, each of these two operations supplements the other and each is made more meaningful by virtue of experience in the other, and second, it is more economical to teach the division facts along with the multiplication facts since division is, in fact, inverse multiplication.

Steps in division

1. To begin with, the work in division should be limited to one-digit division, and done by long division, in which the work representing various steps is written out. The examples should be so chosen that there is neither any carrying involved, nor is there any remainder left at the end e.g. $2\overline{)24}$, $4\overline{)84}$ etc. Later on the children should be taught to solve similar examples by short division. It is more difficult; but it saves time, as in this method, the writing of the quotient is the only writing which is done in solving an example the other operations being done "mentally".

2. The next step toward division with carrying consists in taking up such examples as have one-digit divisors but have remainders, e.g. $4\overline{)\,49}$, $3\overline{)\,68}$, etc.

3. Then, the examples involving carrying should be taken up e.g. $3\overline{)\,72}$, $4\overline{)\,52}$, etc. Children should have had enough practice in solving examples having two-digit quotients, before those having three-digit quotients are undertaken. These examples should gradually increase in difficulty. The hardest will probably be those in which the divisor is 8 or 9 and in which the quotients are in the eighties and the nineties

In this early work in division, the children should understand that each quotient figure is to be placed directly above the last figure of the partial dividend which is being used. There are three reasons for this: (i) it will help the child later to keep track of the dividend digits which he has brought down; (2) it will help when difficulties arise in connection with the appearance of zeros in the quotient; (3) it well help him later in locating a decimal point in the quotient correctly.

In dealing with division examples involving three-digit quotients, it is advisable first to take up those examples in which there is only one carrying operation and when the children get accustomed to such examples, they should undertake to solve those which require two carrying operations.

4. Zeros in the quotient offer much difficulty. Therefore, such examples should be dealt with only after the children have acquired competence enough to solve division examples of the type mentioned above. In the example $5\overline{)\,6521}$, children tend to write 134 as the quotient, leaving 1 as the remainder. Here it is to be emphasized that each time we bring down a figure, we must write another figure in the quotient, and when the figure that is brought down is smaller than the divisor, we must place a 0 in the quotient.

5. Lastly examples with two-digit divisors should be taken up. As the estimation of quotients with two-digit divisors is difficult, examples should be graded as follows :

(*a*) Divisors that are multiples of 10, e.g., 20,30,40, etc.

(*b*) Divisors that are 1 or 2 more than multiples of 10, e.g., 22,31,42 etc

(*c*) Divisors that are 1 or 2 less than multiples of 10, e.g., 19, 28, etc. In an example with 19 as the divisor, the quotient should be estimated on the assumption that the divisor is 20. Similarly when 28 is the divisor, the quotient should be estimated with 30 as the divisor.

(*d*) Divisors that are not in proximity to multiples of 10, e.g., 26,35,37,46. Examples with such divisors are very troublesome, since the estimation of quotients sometimes requires several trials.

XII. Compound Operations

The Basic school child in the very early stages of his school programme has frequent opportunities of experiencing with various kinds of measurement, e.g., length, time, weight, etc. These experiences lead him naturally to the use of compound addition, compound subtraction, compound multiplication and compound division.

Measures of length and distance

The children, while winding the yarn on their winders, can easily be induced to measure the length of the yarn. The winder being one foot long, they would deduce that the length of one round (*tar*) of yarn is 4 feet. In cardboard modelling, they would make measurements in inches and

learn that there are 12 inches in a foot. They would further make use of these units in measuring the heights of their class-mates quarterly or half yearly. Later they would have experiences with the yard stick, measuring sides of their flower-beds or vegetable plots in terms of yards, and discover that a yard contains three feet, or 36 inches. Similarly in expressing longer distances, such as those between the children's homes and the school, or the surrounding places, the children would learn larger units of length—mile and furlong.

In the craft work and other activities of children, there are numerous situations which lend themselves to furnishing adequate practice in the four compound rules. These should be used as they arise.

Measures of time

The children in a Basic school have to learn telling of time from the clock to ascertain their speed of spinning. They learn of time duration when they carry on various activities in the school, They learn the number of days in a week and their names while recording their performance in the craft work from day to day. They study the calendar and learn to tell the names and number of months in a year, when holidays begin and end, when special events, e.g., annual functions, exhibitions, celebrations of national and seasonal festivals take place in the school. By and by the children will learn that there are 24 hours in a day, 60 minutes in an hour and 60 seconds in a minute.

Measures of weight

The measures of weight, with which the children of Basic schools first become familiar are the *tola*, *chatank* and *seer*. These measures are used to weigh cotton in carding and spinning. The maund is a unit used to measure the

produce of a vegetable garden or an agriculture farm. In measuring the weight of the children which is to be done each month, the pound should be introduced. Thus to a resourceful teacher there should be no lack of real examples in all the four compound rules concerning measures of weight.

Measures of Money

In buying craft materials and equipment and in selling the products, the children will deal with units of money—rupee, anna, pice and pie. In keeping accounts of their craft work, they will solve problems in compound rules regarding money.

Collective terms

We use certain collective terms like pair, dozen, gross, etc. in our transactions. We sometimes buy certain articles by the dozen or the gross, e.g., eggs, oranges, bananas, pencils, buttons, etc., because that is more economical. Therefore, the children should be acquainted with these terms when a suitable occasion arises and given some practice in solving problems about them.

XIII. Fraction

Common fraction

Generally children get the idea of one half and one quarter early in life, when a thing is divided into two or four equal parts in order to distribute it among the members of the family. The children in a Basic school have more worthwhile experiences with common fractions in their craft work. While they are carrying on measurements in cardboard modelling and woodwork with a foot rule, they

use $\frac{1}{2}$", $\frac{1}{4}$", etc, Likewise they use $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, of a tola to weigh cotton, *latti*, or *gundi* in spinning, and half, quarter and one-eighth of a seer to weigh seeds and vegetables in gardening. Common fraction may be taken up *just after the children have learnt division as a special form of division.* The preliminary work with fractions should be begun with concrete objects e.g. pancake, orange, melon, square and circular figures etc. The fraction to receive attention first is one-half. This should be followed by one-fourth. Let some familiar object, like a pancake or an orange, be cut into halves. Through the use of questions, call the attention of the children to the fact that there are just two pieces, that these pieces are exactly the same size, and that each one is called $\frac{1}{2}$. Then divide further each piece into halves. The children will see that all these four pieces are of equal size and each is one-fourth or $\frac{1}{4}$. Then help them understand that if one of these pieces is taken away, the remaining three pieces will be called three-fourths or $\frac{3}{4}$.

The four basic rules applied to common fractions

When the children are confronted with problems in which fractional measures of length or weight have to be added or subtracted, they will need to learn the use of the Least Common Multiple and the Highest Common Factor. To provide them adequate practice in the addition and the subtraction of common fractions examples should be graded in difficulty and related to the craft work and other experiences of the children. This principle should also be observed while providing them practice in the multiplication and the division of common fractions.

Decimal fractions

Though our systems of length, weight, money etc. are

not decimal, we use decimal fractions in certain situations. Decimal fractions are used in expressing temperature, rainfall, percentage etc. A foot rule marked in inches and tenths of an inch, and a tape showing feet and tenths of a foot are becoming more popular with our craftsmen and surveyors. The greater convenience of the decimal fraction in computations is the reason for this change. A little practice in computing with measurements made in inches and eighths, followed by computations with measurements made in inches and tenths, will enable the child to decide for himself whether the mixed numbers or the decimals are easier to add, subtract, multiply and divide. The foot rule marked in inches and tenths of an inch is the best aid to the rational teaching of decimal fractions.

Placing the decimal point

Children are notoriously inaccurate in the use of the decimal point. The teacher should see to it that the child is able to estimate the size of the answer while dealing with decimals. Carefully graded sets of exercises must be provided on which he is to practise the mental rounding-off of the numbers and the estimating of the answers, until he grasps the idea and begins to do it well. Afterwards, it is only a matter of asking him frequently to justify the location of the decimal point by his observations about the size of his numbers. For instance, in multiplying 5.15 by 2.98, he should round off 5.15 to 5 and 2.98 to 3 and estimate the product as 15. Thus he can determine that the answer of the above example will have a two-digit number and a decimal fraction and therefore he should place the decimal point after the two digits.

Ratio and proportion

The concept of ratio is allied to that of fraction. Ratio is a number which tells "how many times" a certain quantity is of another quantity; for instance, the ratio of a *panseri* (five-seer weight) to a *seer* is 5, because the former is 5 times as heavy as the latter. It is quite desirable to introduce the term to the children in this commonsense way. The term proportion should not be introduced until ratio is well understood in a practical way. It should probably first arise from the consideration of scale drawings. The children have to make a scale drawing of a model in cardboard modelling or woodwork, before they start working on it. In the higher grades of the Basic school, scale drawings can be used with advantage in planning cultivation of the school farm.

XIV. Business Arithmetic

Percentage

The Basic school children come across the concept of percentage, when they have to calculate the extent of wastage in spinning, or the strength and the evenness of the yarn, or the profit in the craft work.

Since per cent is only another expression for hundredths, its study should be based upon a thorough acquaintance with hundredths ; or the study of per cent should be based upon a clear understanding of our decimal system and particularly upon the use of hundredths

The study of per cent should begin with the comparisons of fractions, as in the wastage involved in spinning from day-to-day class or school attendance, and so on. It should be brought home to the children that the comparisons cannot conveniently be made by the use of common frac-

tions, unless they have the same denominators, so we use decimal fractions. When these are expressed as hundredths, they are called per cents. If on a certain day a child takes slivers weighing 2 tolas and wastes 1/16 of a tola in spinning, and the next day the wastage amounts to 1/8th of a tola when he spins 3 tolas of slivers, which day has he wasted more? We should express the wastage of each day as a common fraction of the weight of the slivers and then change it to hundredths. The first question to arise in the child's mind should be "what part or fraction ?" The second should be, "How many hundredths ?" The third, "What per cent ?"

Examples on per cent should not, however, be limited to the craft work alone. Some practical applications of this concept should be drawn from the business world as well. Suppose, Mohan goes to work in a shoe-store where he is allowed a commission of 5% of his sales. The children should find some interest in discovering how much Mohan will receive for his month's work. Similarly, problems on interest or *profit and loss* involving per cent can be presented.

Interest

In teaching interest, the aim should be to make the children understand interest rather than to enable them to arrive quickly at some rule for finding interest. The children should be able to appreciate that when a sum of one hundred rupees is loaned or deposited in the savings bank for a year, it will yield us one and a half rupee more and that two hundred rupees for the same period will give us three rupees. On the basis of this knowledge the children will understand better how people incur heavy debts at a high rate of interest.

The formula $i=prt$ can be built up only on the foundation

of adequate practice in solving problems on interest by the use of *proportion* or *unitary method.*

Profit and loss

Terms as profit, loss, capital, cost price and selling price can be made quite clear to the children, if they are induced to run a shop retailing the finished products of their craft and agricultural produce.

Profit as a per cent of the cost price

Business men generally calculate their profit as a per cent of the cost price. But sometimes the profit is figured out as a per cent of the selling price, because the selling price is a definite figure, and it is the one quantity in terms of which everything else can be expressed as a part. Salesmen are paid a certain per cent of the selling price in some commercial concerns, advertising expenses are based on the total sales, overhead charges are expressed as a per cent of the total sales. Problems like these should be understood properly by children in the higher grades of a Basic school.

Business principles versus business forms

Teaching of arithmetic and arithmetic text-books in our country, laid much emphasis on business principles in the past almost to the exclusion of business forms e.g., bill, receipt, cash memo, etc. But now there seems to be a tendency towards the reversal of the emphasis. Business forms are sometimes being given undue importance in the school. But for the children of the Basic school age, simple business principles seem to be more important than the forms. The forms can, of course, be used to stimulate

methodical and neat writing of figures. But they should not be treated as ends in themselves, but only as means to an end. More attention should be given to the understanding of the elementary principles of the mathematics of home life and community affairs with which everybody is concerned.

XV. GEOMETRY

Geometry needed in the Basic school

GEOMETRY included in our Middle and High school curriculum is mostly demonstrative geometry which does not generally interest the average pupil in these grades because of its purely theoretical and rigidly logical treatment. But geometry is not merely a series of logical demonstrations. It includes all the forms and designs, we use in our everyday life. Our approach to geometry in the Basic school should be functional, i.e. the children must learn the use of that geometry which is involved in their craft work and other activities, i.e. design, art, drawing etc.

Craft work and drawing

The work in paper-cutting, paper-folding, cardboard modelling, woodwork, and agriculture requires a knowledge of the common geometrical figures—rectangle, square, circle, triangle, regular polygons of five, six and eight sides, cube, cuboid, cylinder, cone etc.. Each of them should be taken up, when a need for it arises. The children should learn to represent them by drawings and discover their chief characteristics through measurement. The teacher may also acquaint the children with these figures while illustrating

some of the arithmetical concepts and rules e.g. fractions, per cents, ratios, areas, volume, etc.

Graphs

Graphs should be regarded as a means of illustrating other topics rather than as a topic of study in themselves. For instance, bar graphs can be used to show the relative heights or weights of members of the class, classwise and monthwise income and expenditure in craft, attendance, and so on. Certain facts in social studies can be made more vivid by the use of graphs. For example, the graphical representation of population and production statistics or that of the national wealth of various countries can immensely help to clarify the ideas concerned.

Areas and volumes

In gardening and cardboard modelling, the children are early faced with situations which cannot be solved without a knowledge of areas. They have to calculate, for instance, how much cardboard would be needed to make a model of the given specifications, or how much seed would be required to sow a plot of the given dimensions. These problems involve the concept of area. The children must understand that area can be measured only by a unit of surface, and, therefore this unit is a square measure.

Problems involving volume arise in woodwork and agriculture. The pupils have to estimate the quantity of wood needed for a piece of furniture of the given specifications, or the amount of money required for digging a well of the given dimensions. In teaching volume, it must be made clear that volume is measured in terms of space units, which are cube measures.

XVI. Algebra

Formula

Being a general and abstract form of arithmetic, algebra does not seem to be a suitable subject of study in the Basic school. But it can be introduced in an informal way to facilitate work in arithmetic and geometry. The children should be made to realize that in expressing a rule or principle by means of one letter abbreviations much time is saved. When we write $i=prt$, we mean that the interest can be calculated by multiplying the principal, the rate per cent and the time. Similarly $a=lb$ is a compact expression denoting that the area of a rectangle is the product of its length and breadth, or $c/d=\pi$ expresses that the ratio of the circumference and diameter of a circle is equal to π or 3.14 approximately. We call these abbreviated sentences formulas. Thus the formula represents the briefest way to express a fact or a rule. The systematic use of such a compact symbolism will materially improve the written work of the children and they will realize that it saves writing without sacrificing clarity of expression.

By using such formulas the children will learn the following things in algebra :—

1. *The indication of multiplication* by means of two or more letters, or a number and a letter or more letters, written side by side with no sign between them.

2. *Substitution.* While doing this, different kinds of numbers viz., common fraction, mixed numbers and decimals should be given to provide opportunities for review.

3. *Translation.* The children should be asked to

state the fact in the algebraic language and also to translate the algebraic statement into words.

4. *The formula as a rule for computation.* The children should understand whether to multiply or divide, and so on.

Exponents

In the Basic school the work with exponents will be limited to only the *second* and the *third power*. The concept of exponent should be clarified by means of concrete examples. The formula for the area of a square should be used to introduce the first exponent. $A=s\times s$, or s^2. The significance of the new symbol and of the name should be brought home to the children that s^2 is the area of the square whose side is s. Similarly the children should understand that the area of a circle $A=\pi r^2$, if r is the radius of the circle. In order to concretize the concept of the third power, the formula for the volume of a cube i.e. $V=s^3$ should be used.

Equations

The work with equations will be confined to the simple equation. The children should be led to it through the use of formulas they have learnt. Suppose two boys are to have rectangular plots of the same area in the vegetable garden ; the first is 180 square feet in area, and the second is 15 feet long ; how wide must it be made ? After making the drawing the children will write the formula $A=lb$, and substitute the known numbers, getting $180=15b$. Thus they are led to the equation $15b=180$ and they have to find out how mich is b ? The equation suggests that they must divide.

The first step in the use of the equation is to make the

children see what questions are implied in it. They learn to make a distinction between a formula and an equation that the former states a fact, while the latter asks, or at least suggests, a question.

Simple equations of this type can be used with advantage by the children in the upper grades to solve various problems in arithmetic and geometry. Problems arising from the formula for the simple interest $i=prt$, or for the circumference of a circle $c=2\pi r$, and the like will provide the children adequate situations to use simple equations.

This is enough as an introduction to algebra in the Basic school. It rules out : (1) The four operations, except the very simple steps used in the solution of the equations. (2) Negative numbers and rules for signs. At this stage the minus sign is used to indicate subtraction, or a shortage, and nothing else.

(3) Factorization and the parenthesis, except as used in the formula for the perimeter of a rectangle, or for the area of the four walls of a room and other simple cases of the kind.

A systematic treatment of these and similar topics of algebra is a matter fit to be taken up at the Post-Basic stage.

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